Phoen*iX* Cleanroom Database
Process Flow Module

Application Note
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Information management for MST cleanroom processes

A systematic and efficient approach in managing and preserving the knowledge and expertise in MST cleanroom environment by using Phoen*iX* process flow module

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1. Introduction

Documentation of the cleanroom activities is required to preserve the knowledge about the processes and the technologies involved; hence different users with different levels of expertise can obtain the relevant information easily.

However, a documentation for the micro's and nano's cleanroom processes is difficult to realize because of the diverse technologies involved[1] .

The Process Flow Module in the PhoeniX Cleanroom Database is a tool to manage the documentation for the micro's and nano's cleanroom processes. It offers the flexibility to implement various processes and technologies affected. Nevertheless, its thoughtfully defined hierarchy and templates secure the communication standardization.

When the database is managed correctly, the available processes is accessible considerably. Furthermore, the quality improvement and most of the validation process will be automatically accomplished also.

PhoeniX ProcessFlowDB module can be extended to the OperatorDB module to incorporate the data's digestion. The output data from the equipments can be registered as the input of the statistical process control for design iterations by using the simlink. Scripts can perform the statistical process control, and also can send an automatic warning message and email when a deviation is detected.

The purpose of this application note is to exemplify the development of an effective cleanroom database by using the PhoeniX Process Flow Module. The focus of this note is not on the technological issues, but on the documentation and the verification aspects.

The case study for this note, because of its well described technology, is the process flow of the optical core SiON by using the PECVD and RIE processes.

2. The Hierarchy Of The Process Flow Database

Assume that the people that are involved in the cleanroom activities can be grouped based on their major expertise:

- **Equipment managers**
  Various equipments are available in the clean room, all with specific purposes and capabilities. Equipment managers are the experts in the usage and the maintenance of these equipments. They also give courses to use the equipments.
- **Operators**
  Operators are the executors of the process flows; which are typically made by the designers. The operators are the experts in handling the wafers with the cleanroom's equipments. They ensure that the process flows consist of the correct steps (which ideally are also reproducable).
- **Designers**
  Designers are the experts in the technology applications, designs and simulations. Since they focus on the product optimization by the available technologies, they often have limited knowledge about the usage of the cleanroom's equipments and the processes involved.

In reality, these functions are not always clearly distinguishable. These coarse function categorizations are used as a reference to compose the hierarchy of the database.

The Process Fow DB module in PhoeniX CR database consists of four levels of hiearchy, which are shortly described at figure 2.1 below:

1Proceedings COMS 2003 “Trends in micro and nano software” by ir.N.Olij, ir.A.F.Bakker, dr.ir.H.H.van den Vlekkert.

PhoeniX Cleanroom Database
Module : Process Flow Database

Hierarchy	General description	Examples	Process validation	Quality improvement	Involved Expertises
Equipment	▪ Define the cleanroom's equipment (1)	▪ Piranha bath. ▪ Hotplate. ▪ BLE gamma 60.	▪ Define the forbidden and the available materials (2) for the equipment.	▪ Create the new versions of the available equipment.	▪ Equipment managers.
Process Steps	▪ Define the usage of equipment in the process step.	▪ The cleaning step by using the piranha bath. ▪ The baking step by using the hotplate. ▪ The exposure step by using the mask aligner.	▪ Validation of the materials and the equipment used in a process step. ▪ Define the required preceding steps and the forbidden proceeding steps.	▪ Update the version of the equipment used in a process step. ▪ Create the new versions of the available process steps.	▪ Equipment managers. ▪ Operators.
Process Blocks	▪ Consist of a series of process steps to obtain a single development progress, e.g. a mask layer.	▪ The photolithography block to obtain the mask layer consists of several process steps : - the cleaning steps - the baking steps - the exposure step	▪ Validation of the relation among the process steps used in a process block. ▪ Define the required preceding blocks and the forbidden proceeding blocks.	▪ Update the version of the process steps used in a process block ▪ Create the new versions of the available process blocks.	▪ Operators.
Process Flows	▪ Consist of a series of process blocks to obtain a component, e.g. optical core SiON.	▪ The Optical core SiON flow is developed by several process blocks : - the deposit block - the photolitography block - the etching block - the measurement block	▪ Validation of the relation among the process blocks used in a process flow. ▪ Detail overview of the used proceses.	▪ Update the version of the process blocks used in a process flow. ▪ Create the new versions of the available process flows.	▪ Designers.
Masks	▪ Define the mask that is used by the process steps.				

Notes :
(1) The equipment's categories and the equipment's parameters are defined in the Core DB.
(2) The materials, the material categories and the material's properties are defined in the Core DB.

Figure 2.1 The hierarchy of the process flow database.

Each level of the hierarchy has a specific menu. Each menu contains unique templates. The menu and their templates function as communication standard and knowledge management. This way the reuse, the quality improvement, and the validation of the defined processes can be realized.

The usage of the menu/templates inside the hierarchy, and the definition of the processes to develop a SiON optical core, will be briefly explained at section 3,4 and 5.

Section 3 will focus on the process development topic, while section 4 will bring up the issue about process validation. The quality improvement will be mentioned at section 5.

3. The Development Of The Process Flow Database

One important issue in developing a database is managing the information effectively. This section is dedicated to show a possibility to sufficiently document the processes to develop an optical core by using the SiON technology.

PhoeniX Cleanroom Database
Module : Process Flow Database

Menu / Templates

Development

Hierarchy	Control	Result	Cross-section	Action	Steps & Blocks	Summary & Overview (1)	Reference
Equipments	The control buttons of the equipment.	Only for measurement equipment.					References to the local files and websites
Process Steps	The public(2) / private controls of the equipment.	The public(2) / private results of the measurement equipment.	The cross-section profile of the wafer after the process step, e.g. uniform etching /deposition.	The list of actions in using the equipment in a process step.			References to the local files and websites
Process Blocks	- The controls inherited from the process steps. - The controls of the blocks.	- The results inherited from the process steps. - The results of the measurement blocks. - The result estimation.			The series of process steps that build a process block.		References to the local files and websites
Process Flows	- The controls inherited from the process blocks. - The controls of the flows.	- The results inherited from the process blocks. - The results of the measurement flows. - The result estimation.			The series of process blocks that build a process flow.	The summary and the detailed overview of the processes involved.	References to the local files and websites

The mathematical expression relates the control and the result (3)

Masks (4)	Path	Filename	Polarity	Layer name
	The path of the mask files.	The name of the mask files.	The polarity of the mask (inside black/white).	The name of the layer.

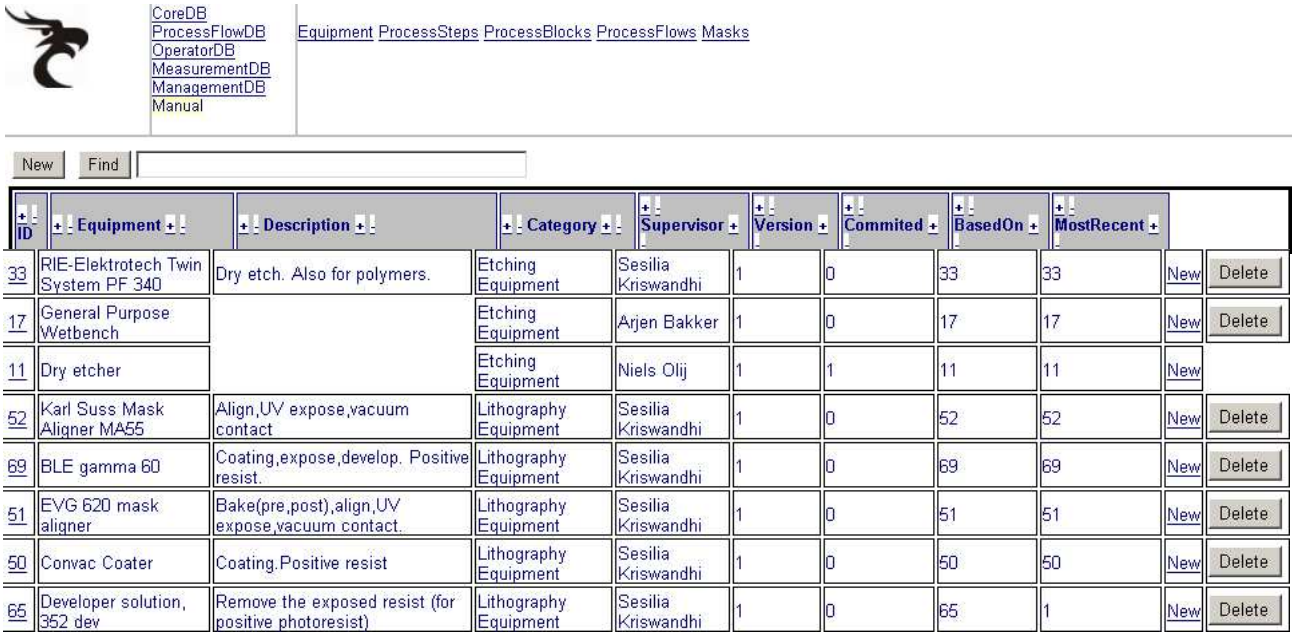
Notes : (1) These tasks are automatically done by the software.
(2) The public controls/results will become the inherited controls/results in the higher level processes.
(3) The mathematical expression interconnects the controls and the results from each level of hierarchy, e.g. expected result from process flow is a function of the controls from process block or equipment.
(4) The mask's templates defines the masks that are used in the process steps.

Figure 3.1 The menu/templates for process development in the Process Flow Database.

3.1 The Equipment

First the equipments that will be used in the processes should be defined. Below are some equipments that are used for the etching and lithography processes.

The list of the available equipments can be seen at the ProcessFlowDB/Equipment.



ID	Equipment	Description	Category	Supervisor	Version	Commited	BasedOn	MostRecent		
33	RIE-Elektrotech Twin System PF 340	Dry etch. Also for polymers.	Etching Equipment	Sesilia Kriswandhi	1	0	33	33	New	Delete
17	General Purpose Wetbench		Etching Equipment	Arjen Bakker	1	0	17	17	New	Delete
11	Dry etcher		Etching Equipment	Niels Olij	1	1	11	11	New	
52	Karl Suss Mask Aligner MA55	Align,UV expose,vacuum contact	Lithography Equipment	Sesilia Kriswandhi	1	0	52	52	New	Delete
69	BLE gamma 60	Coating,expose,develop. Positive resist.	Lithography Equipment	Sesilia Kriswandhi	1	0	69	69	New	Delete
51	EVG 620 mask aligner	Bake(pre,post),align,UV expose,vacuum contact.	Lithography Equipment	Sesilia Kriswandhi	1	0	51	51	New	Delete
50	Convac Coater	Coating.Positive resist	Lithography Equipment	Sesilia Kriswandhi	1	0	50	50	New	Delete
65	Developer solution, 352 dev	Remove the exposed resist (for positive photoresist)	Lithography Equipment	Sesilia Kriswandhi	1	0	65	1	New	Delete

Figure 3.1.1 List of some cleanroom equipments. The plus and the minus signs are used to arrange the contents of each menu in alphabetical order. Here the contents of the "Category" menu are arranged in alphabetical order .

The "Delete" buttons are available only for the equipments that are not committed yet. The committed equipments cannot be deleted nor modified anymore, but one can still make a new version of it[2].

Clicking the ID number of an equipment will enter the menu/template of the equipment (figure 3.1.2).

Figure 3.1.2 The menu/template of the equipment. *The "Result" menu is dedicated only for the measurement equipment.*

2Refer to the online Manual for the elaborate explanation about how to use the PhoeniX database.

3.1.1 The References Menu

Additional information can be set as the references.

Note: *The references in a form of the result files are recommended to be placed in the Process Step or Process Block hierarchy, since they are related to the measurement processes instead of measurement equipment.*

Figure 3.1.1.1 The references for the RIE-Elektrotech Twin System PF340.

3.2 The Process Steps

Process steps can be defined as a sufficient step-by-step description of how to use an equipment to do a cleanroom process. For example: a step-by-step description to use RIE to etch a wafer are the venting step, the vacuum step, and the parameter setting step.

Process steps are the **key** to develop an effective database. Process steps should be thoughtfully defined as they are the constructors of the process flows. Adequate process steps will develop a database that is re-usable and is able to validate the process flows automatically.

Adequate process steps are not necessarily a step-by-step manual of the equipment's usage.

Most cleanroom teams provide a well-defined manual for the usage of equipment. Besides, recent equipments usually have a clear user manual with build-in software to help the user. The existing information, including the result files, can be set as references inside the relevant process step.

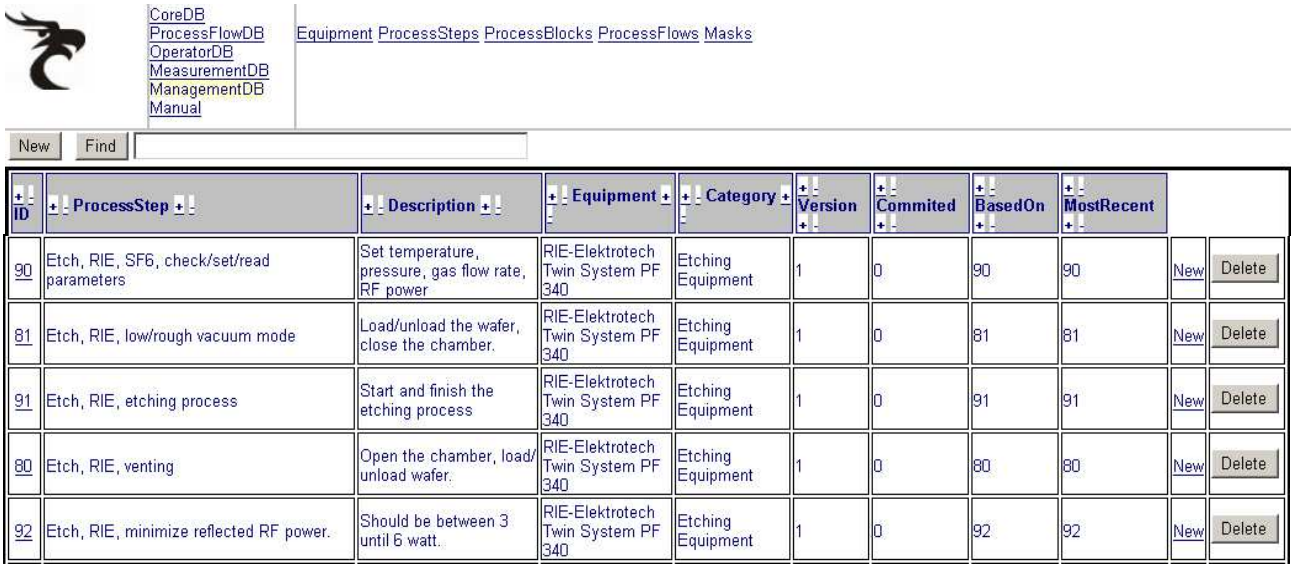
What most cleanroom teams do not have are a well-defined and a self-validated process flow module that can e.g. avoid the forgotten process steps /blocks; and this should be the purposes of anyone that designs the process steps : *the process steps should be re-usable and should be able to validate the process blocks/flows that they build.*

We strongly recommend that some time should be spent among all expertises in the cleanroom to make the steps wisely and fairly complete, even if some may think "*this will never be used*". The experiences show that if an exception might exist, it will most likely occur sooner than later. Being prepared for this will save considerable effort in the future.

3.2.1 The Re-usable And The Specifically Defined Process Steps

Although one would prefer to have the re-usable process steps, some steps may have to be specifically defined due to the specific purpose.

Below are the list of the available process steps to etch a wafer by using equipment RIE-Elektrotech Twin System PF340. Several etching gases for different purposes are available in this equipment. Dus the process step to set the equipment parameters has to be specifically defined in accordance with the chosen etching gas.



ID	ProcessStep	Description	Equipment	Category	Version	Commited	BasedOn	MostRecent		
90	Etch, RIE, SF6, check/set/read parameters	Set temperature, pressure, gas flow rate, RF power	RIE-Elektrotech Twin System PF 340	Etching Equipment	1	0	90	90	New	Delete
81	Etch, RIE, low/rough vacuum mode	Load/unload the wafer, close the chamber.	RIE-Elektrotech Twin System PF 340	Etching Equipment	1	0	81	81	New	Delete
91	Etch, RIE, etching process	Start and finish the etching process	RIE-Elektrotech Twin System PF 340	Etching Equipment	1	0	91	91	New	Delete
80	Etch, RIE, venting	Open the chamber, load/ unload wafer.	RIE-Elektrotech Twin System PF 340	Etching Equipment	1	0	80	80	New	Delete
92	Etch, RIE, minimize reflected RF power.	Should be between 3 until 6 watt.	RIE-Elektrotech Twin System PF 340	Etching Equipment	1	0	92	92	New	Delete

Figure 3.2.1.1 The etching process steps by using the RIE-Elektrotech Twin System PF340. This list can be seen at the ProcessFlowDB/ProcessSteps, sorting the e.g. “Equipment” in alphabetical order.

The process steps with ID [81],[91],[80],[92] are accessible for all process blocks that use the equipment RIE-Elektrotech Twin System PF340. *Process Block is the next level of hierarchy after Process Step (refer to figure 3.1).*

The process step with ID [90] is dedicated only for a specific process block that use the equipment RIE-Elektrotech Twin System PF340 **and the etching gas SF6.**

Clicking the ID number of the process step will reveal the menu of the process step.

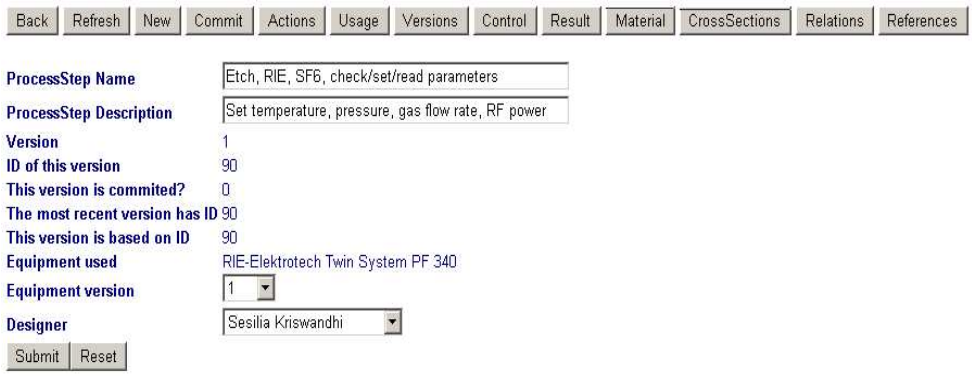


Figure 3.2.1.2 The menu/template of the process step with ID 90. *The “Result” menu is only available when a measurement equipment is used.*

3.2.2 The Actions Menu

A brief explanation about the actions to perform the process step can be written down in this window.

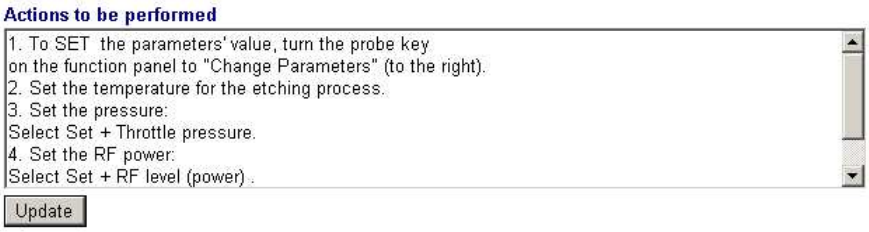

Actions to be performed
1. To SET the parameters' value, turn the probe key
on the function panel to "Change Parameters" (to the right).
2. Set the temperature for the etching process.
3. Set the pressure:
Select Set + Throttle pressure.
4. Set the RF power:
Select Set + RF level (power) .
Update

Figure 3.2.2.1 A brief explanation about the actions to perform the process step with ID 90 “Etch,RIE,SF6, check/ set/read parameters”.

3.3 The Process Blocks

As previously mentioned, process steps are a step-by-step description of how to use an equipment to do a cleanroom process.

Process block consists of the series of process steps that are aligned properly so that a cleanroom process is defined.

Clicking the ID number of process block “Etch,RIE,SF6 (ID 36) will show the menu of the process block. Clicking the “Steps” menu will reveal the process steps used and their proper alignment to define the etching process.

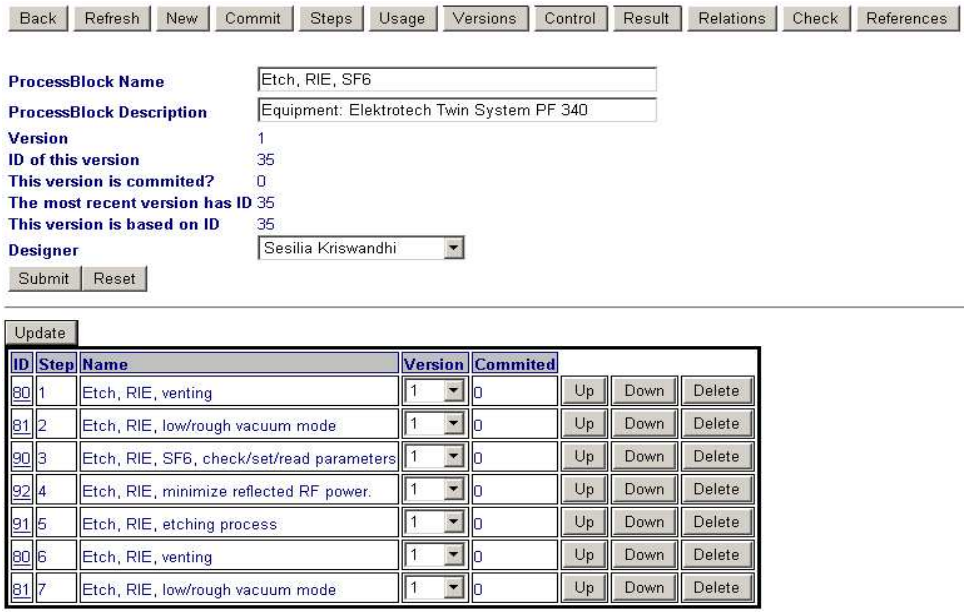


Figure 3.3.1 The process steps used in the process block “Etch, RIE, SF6” (process block ID 35).

3.4 The Process Flows

Process flow consists of the series of process blocks that are aligned properly so that a process to develop a component; e.g. SiON optic core; is defined.

Clicking the ID number of process flow “Optic core SiON (ID 7) will show the menu of the process flow. Clicking the “Blocks” menu will reveal the process blocks used and their proper alignment to define the SiON optic core development.

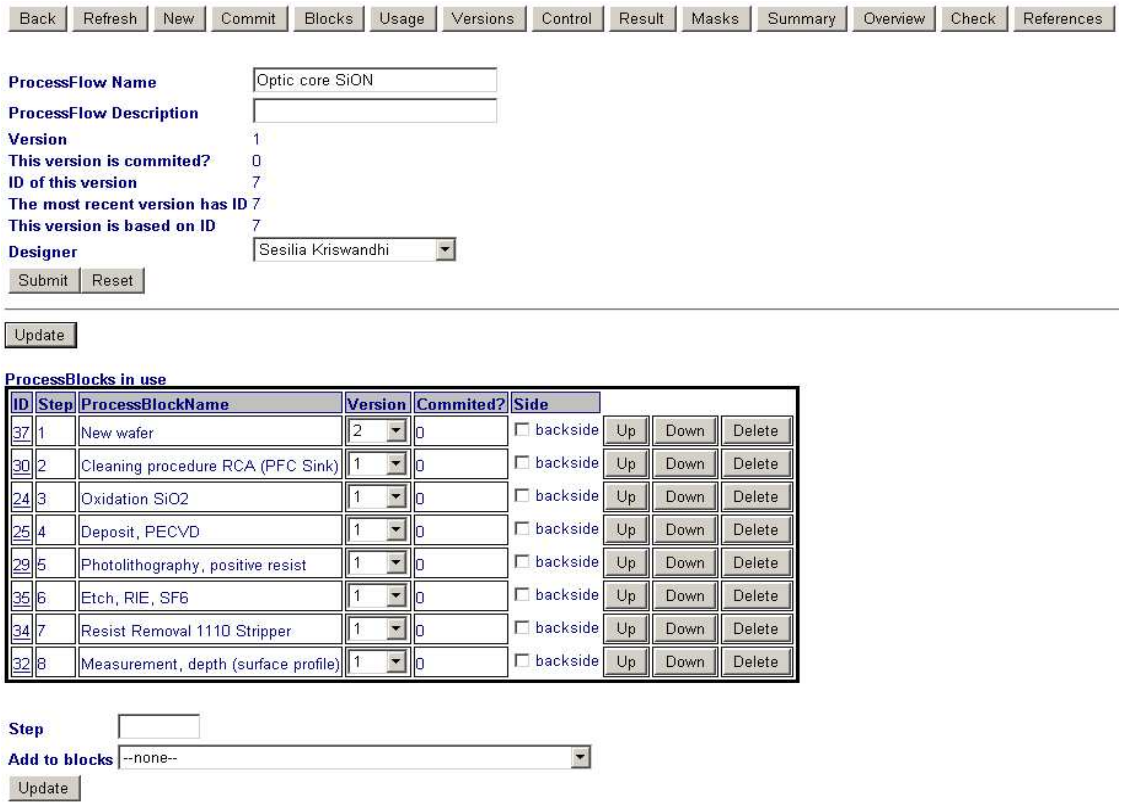


Figure 3.4.1 The process blocks used in the process flow to develop optic core SiON (process flow ID 7).

3.4.1 The Summary And The Overview

Clicking the "Summary" menu will show the list of the processes and the equipments involved in the process flow. The "Overview" menu is the detailed version of the summary.

The summary and the overview are generated automatically by the database. Clicking on the underlined process and equipment will enter the templates of the process and the equipment themselves.

Mask to be used: (ID=1) v-groove mask version 1 (\\\\localhost\\home\\noj\\test.gds)

Cross section Settings: Length 1000, Rotation 0, Position (0,0)

Step	xStep	Name	Equipment	Side
Block	**1**	**New wafer**		
1	1	Select: a wafer	Wafer selector	Front Side
Block	**2**	**Cleaning procedure RCA (PFC Sink)**		
2	1	Remove organic coating (Piranha bath)	PFC Sink: Piranha process bath	Both Sides
3	2	Clean, DI water	Container: De-Ionized water	Both Sides
4	3	Remove organics+some metal contaminant (RCA base)	PFC Sink: RCA process bath,base	Both Sides
5	4	Clean, DI water	Container: De-Ionized water	Both Sides
6	5	Remove native oxide layer (HF dip)	PFC Sink : (buffered) HF dip	Both Sides
7	6	Clean, DI water	Container: De-Ionized water	Both Sides
8	7	Remove atomic+ionic contaminant (RCA acid)	PFC Sink: RCA process bath, acid	Both Sides
9	8	Clean, DI water	Container: De-Ionized water	Both Sides
10	9	Dry, spin	Spinner at BTC 320	Both Sides
Block	**3**	**Oxidation SiO2**		
11	1	Oxidate,dry,check/set/read parameters	A2 Anneal	Front Side
Block	**4**	**Deposit, PECVD**		
12	1	Deposit,PECVD,venting	PECVD-Elektrotech Twin System PF 340	Front Side
13	2	Deposit,PECVD,vacuum mode	PECVD-Elektrotech Twin System PF 340	Front Side
14	3	Deposit,PECVD,check/set/read parameters.	PECVD-Elektrotech Twin System PF 340	Front Side
15	4	Deposit,PECVD,minimize reflected RF power	PECVD-Elektrotech Twin System PF 340	Front Side
16	5	Deposit,PECVD,deposition process	PECVD-Elektrotech Twin System PF 340	Front Side
17	6	Deposit,PECVD,venting	PECVD-Elektrotech Twin System PF 340	Front Side
18	7	Deposit,PECVD,vacuum mode	PECVD-Elektrotech Twin System PF 340	Front Side
Block	**5**	**Photolithography, positive resist**		
19	1	Coat,solvent HDMS	Convac Coater	Both Sides
20	2	Coat,positive resist Shipley 1400	Convac Coater	Both Sides
21	3	Bake, soft/pre-bake, hotplate	Hotplate	Both Sides
22	4	Expose,UV source, Karl Suss	Karl Suss Mask Aligner MA55	Front Side
23	5	Develop, solution 352 Dev	Developer solution, 352 dev	Front Side
24	6	Bake, hard/post-bake, hotplate	Hotplate	Both Sides
Block	**6**	**Etch, RIE, SF6**		
25	1	Etch, RIE, venting	RIE-Elektrotech Twin System PF 340	Front Side
26	2	Etch, RIE, low/rough vacuum mode	RIE-Elektrotech Twin System PF 340	Front Side
27	3	Etch, RIE, SF6, check/set/read parameters	RIE-Elektrotech Twin System PF 340	Front Side
28	4	Etch, RIE, minimize reflected RF power.	RIE-Elektrotech Twin System PF 340	Front Side
29	5	Etch, RIE, etching process	RIE-Elektrotech Twin System PF 340	Front Side
30	6	Etch, RIE, venting	RIE-Elektrotech Twin System PF 340	Front Side
31	7	Etch, RIE, low/rough vacuum mode	RIE-Elektrotech Twin System PF 340	Front Side
Block	**7**	**Resist Removal 1110 Stripper**		
32	1	Remove photoresist,1110 stripper	Resist removal solution, 1110 Stripper	Both Sides
33	2	Clean, Isopropyl Alcohol	Container: Isopropyl Alcohol	Both Sides
34	3	Clean, DI water	Container: De-Ionized water	Both Sides
35	4	Dry, spin	Spinner at BTC 320	Both Sides
Block	**8**	**Measurement, depth (surface profile)**		
36	1	Measure: depth	Dektak 8 Profilometer	Front Side

Figure 3.4.1.1 The summary of the processes and the equipments involved to develop optic core SiON (process flow ID 7).

3.5 The Control And The Result

The control and the result are the links among the processes defined in different levels of hierarchy. They communicate by using the mathematical expression, e.g. the result in the process flow level is a function of the controls in the process blocks or in the equipments.

The available mathematical functions and expressions for ProcessFlowDB are listed in the Online Manual of PhoeniX Database.

3.5.1 The Control Menu In the Equipment

The control buttons of the equipment should be defined completely, so that they can be used in various process steps and process blocks.

For example, the RIE-Elektrotech Twin System PF340 has several gases to etch the wafer. All the available gases have to be defined in the ProcessFlowDB/Equipment level. Further in the higher hierarchy (ProcessFlowDB/ProcessSteps or ProcessFlowDB/ProcessBlocks), the specific gas(es) used to etch can be assigned depends on the relevant process.

Clicking the "Control" menu will reveal the controls of the equipment.

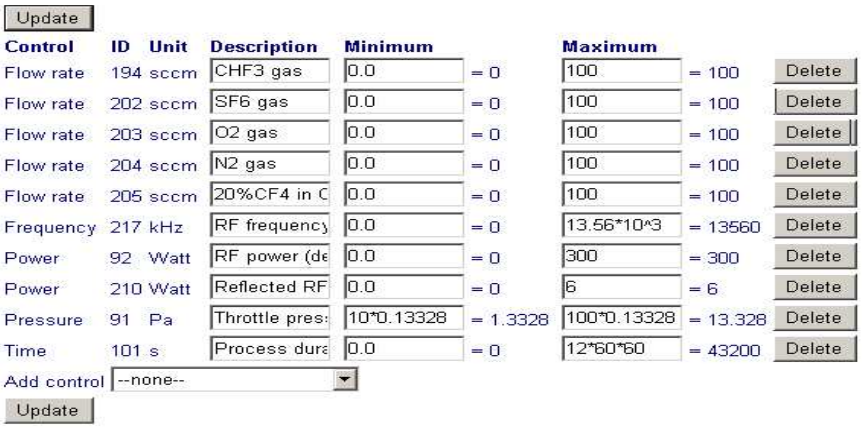

Update
Control ID Unit Description Minimum Maximum
Flow rate 194 sccm CHF3 gas 0.0 = 0 100 = 100 Delete
Flow rate 202 sccm SF6 gas 0.0 = 0 100 = 100 Delete
Flow rate 203 sccm O2 gas 0.0 = 0 100 = 100 Delete
Flow rate 204 sccm N2 gas 0.0 = 0 100 = 100 Delete
Flow rate 205 sccm 20%CF4 in C 0.0 = 0 100 = 100 Delete
Frequency 217 kHz RF frequency 0.0 = 0 13.56*10^3 = 13560 Delete
Power 92 Watt RF power (de 0.0 = 0 300 = 300 Delete
Power 210 Watt Reflected RF 0.0 = 0 6 = 6 Delete
Pressure 91 Pa Throttle pres 10*0.13328 = 1.3328 100*0.13328 = 13.328 Delete
Time 101 s Process dura 0.0 = 0 12*60*60 = 43200 Delete
Add control --none--
Update

Figure 3.5.1.1 The controls of RIE-Elektrotech Twin System PF340 (equipment ID 33).

3.5.2 The Control Menu In The Process Step

The controls of the process step are the controls of the equipment used by that process step.

At this level, we assign which controls of the equipment are relevant to the process step. The relevant controls are assigned as public so they can be used in the higher hierarchy.

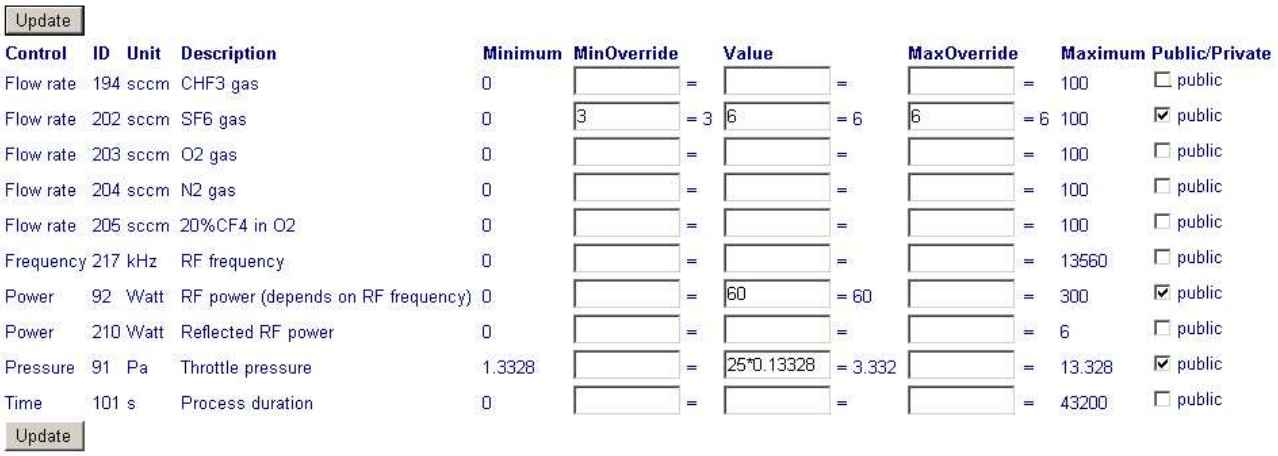

Update
Control ID Unit Description Minimum MinOverride Value MaxOverride Maximum Public/Private
Flow rate 194 sccm CHF3 gas 0 = = = 100 public
Flow rate 202 sccm SF6 gas 0 3 = 3 6 = 6 6 = 6 100 public
Flow rate 203 sccm O2 gas 0 = = = 100 public
Flow rate 204 sccm N2 gas 0 = = = 100 public
Flow rate 205 sccm 20%CF4 in O2 0 = = = 100 public
Frequency 217 kHz RF frequency 0 = = = 13560 public
Power 92 Watt RF power (depends on RF frequency) 0 = 60 = 60 = 300 public
Power 210 Watt Reflected RF power 0 = = = 6 public
Pressure 91 Pa Throttle pressure 1.3328 = 25*0.13328 = 3.332 = 13.328 public
Time 101 s Process duration 0 = = = 43200 public
Update

Figure 3.5.2.1 Assign the controls for the process step "Etch,RIE,SF6,check/set/read parameters" (process step ID 90). The controls assigned as public will be used in the higher hierarchy; in this case the process block that define the etching process by using gas SF6 (process block ID 35 – figure 3.5.3.1 below).

The value of the controls, also the range [min,max], can be adjusted in accordance with the process.

Note: *the range of the values in the process step cannot exceed the one determined in the equipment. A process cannot be performed by an equipment if the required range of the process is beyond the capacity's range of the equipment.*

3.5.3 The Control Menu In the Process Block -- the inherited and the local controls --

There are two types of controls in the process block: the inherited and the local ones. Both are inside the "Control" menu.

The inherited controls are the public controls of the process steps used in the process block.

Inherited controls

Update

BStep	StepName	Control	ID	Unit	Description	Minimum	Default	Override		Maximum
1	Etch, RIE, venting	Time	101	s	Process duration	0	10		=	43200
2	Etch, RIE, low/rough vacuum mode	Time	101	s	Process duration	0		10	= 10	43200
3	Etch, RIE, SF6, check/set/read parameters	Flow rate	202	sccm	SF6 gas	3	6		=	6
3	Etch, RIE, SF6, check/set/read parameters	Power	92	Watt	RF power (depends on RF frequency)	0	60	300	= 300	300
3	Etch, RIE, SF6, check/set/read parameters	Pressure	91	Pa	Throttle pressure	1.3328	3.332		=	13.328
4	Etch, RIE, minimize reflected RF power.	Power	210	Watt	Reflected RF power	0	3		=	6
5	Etch, RIE, etching process	Time	101	s	Process duration	0	900	20*60	= 1200	43200
6	Etch, RIE, venting	Time	101	s	Process duration	0	10		=	43200
7	Etch, RIE, low/rough vacuum mode	Time	101	s	Process duration	0		10	= 10	43200

Figure 3.5.3.1 The inherited controls from each proces steps used in the process block "Etch, RIE, SF6" (process block ID 35)

The local controls are the controls defined specifically for the process block. These controls can be assigned as public if they are meant to be accessible at the next level of hierarchy (process flow and batches).

Local controls

Control	ID	Unit	Description	Minimum	Value	Maximum	Public/Private	
Flow rate	49	sccm	SF6 gas	3 = 3	3 = 3	6 = 6	public	Delete
Time	42	s	Etching dura	900 = 900	20*60 = 1200	2400 = 2400	public	Delete

Add control --none--

Update

Figure 3.5.3.2 The local controls of process block "Etch, RIE, SF6" (process block ID 35). Assign as public, they will be accessible at the higher hierarchy, in this case the process flow "Optic core SiON" (process flow ID 7).

3.5.4 The Control And The Result in the Process Flow -- the mathematical expression to relate the control and the result --

The relation between the control of a cleanroom equipment and the result of a measurement equipment can be defined by mathematical expression.

Click the "Control" menu in the process flow "Optic core SiON" (process flow ID 7) reveals the inherited controls from the process blocks.

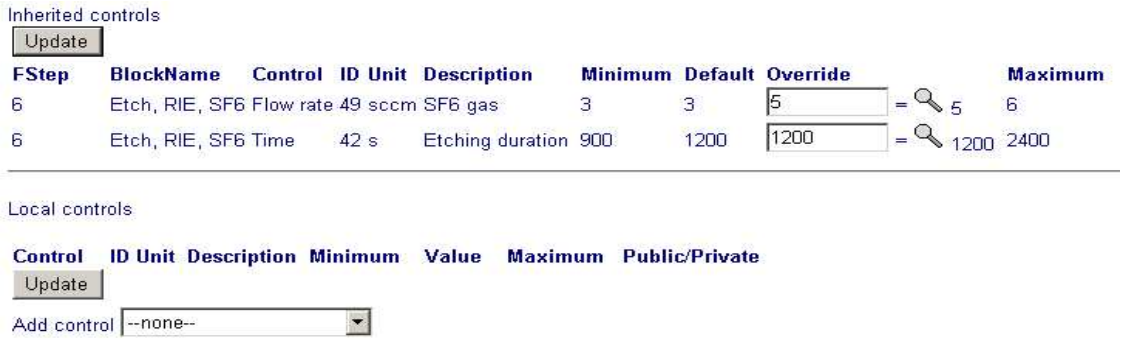

Inherited controls
Update
FStep BlockName Control ID Unit Description Minimum Default Override Maximum
6 Etch, RIE, SF6 Flow rate 49 sccm SF6 gas 3 3 5 = 5 6
6 Etch, RIE, SF6 Time 42 s Etching duration 900 1200 1200 = 1200 2400
Local controls
Control ID Unit Description Minimum Value Maximum Public/Private
Update
Add control --none--

Figure 3.5.4.1 The inherited control from process block "Etch, RIE, SF6" (process block ID 35). *Note: the local controls of the process flow will become the inherited controls of the batches.*

The process flow "Optic core SiON" uses a measurement equipment (Dektak) to measure the etch depth. Click the "Result" menu shows the results of the process flow "Optic core SiON" (process flow ID 7).

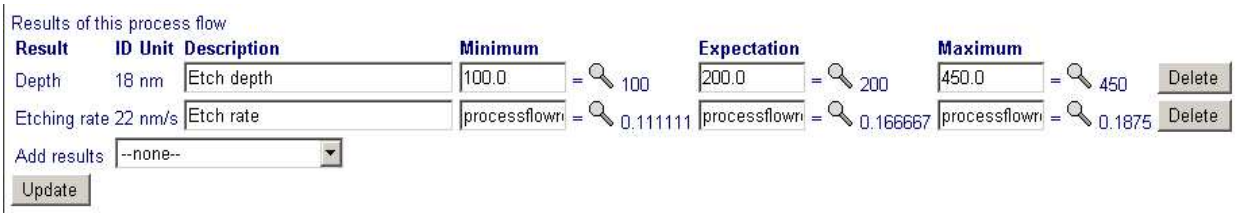

Results of this process flow
Result ID Unit Description Minimum Expectation Maximum
Depth 18 nm Etch depth 100.0 = 100 200.0 = 200 450.0 = 450 Delete
Etching rate 22 nm/s Etch rate processflowr = 0.111111 processflowr = 0.166667 processflowr = 0.1875 Delete
Add results --none--
Update

Figure 3.5.4.2 The results of the process flow "Optic core SiON" (process flow ID 7).

The etch depth, together with the duration time of the etching process, are used to obtain the etch. The etch rate is the etch depth devided by the duration time of the etching proces

Click the magnifying glass beside the "Expectation" value of "Etching rate" reveals the mathematical expressions used to define the relation between the flow result and the block control.

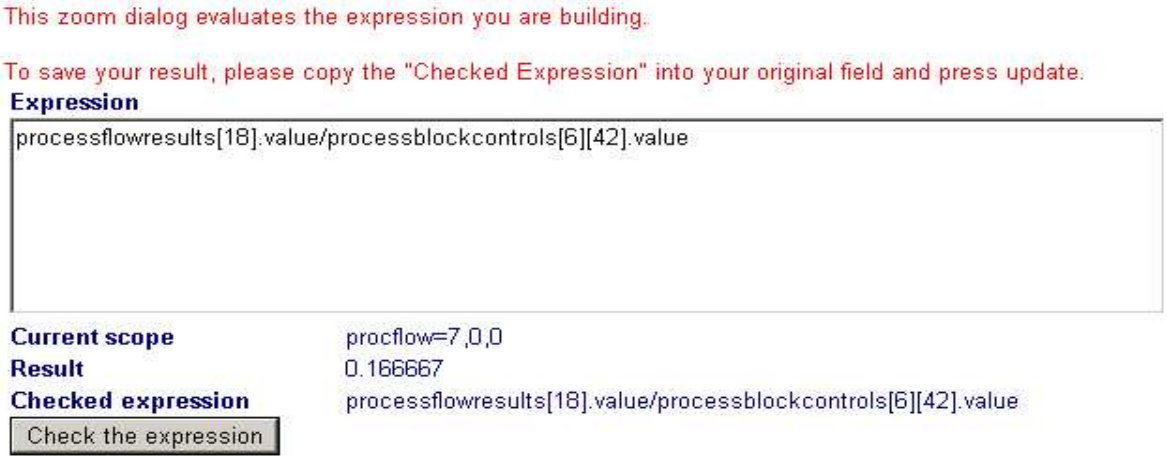

This zoom dialog evaluates the expression you are building.
To save your result, please copy the "Checked Expression" into your original field and press update.
Expression
processflowresults[18].value/processblockcontrols[6][42].value
Current scope procflow=7,0,0
Result 0.166667
Checked expression processflowresults[18].value/processblockcontrols[6][42].value
Check the expression

Figure 3.5.4.3 The mathematical expression to define the etch rate as the etch depth (process flow result with ID 18 – refer to the "ID" at figure 3.5.4.2) devided by the etcing's duration time (process block control number 6 with ID 42 – refer to the "FStep" and "ID" at figure 3.5.4.1).

The mathematical expressions to define the minimum and the maximum values of the etch rate are obtained in the similar way, replacing the "value" with "minvalue" and "maxvalue" respectively, e.g. processflowresults[18].minvalue/processblockcontrols[6][42].minvalue.

The mathematical expressions are able to interconnect the controls and the results from different levels of the hierarchy. The higher level controls can be used to specify the lower level controls. The results of the current level can be used to specify the consecutive controls, and also the results in the higher level.

Thus the process flow controls can be used to set the controls of the first block in the flow. The controls and the results of the first block can be used for the second block in the flow. The flow results can be a combination of the controls and results of the applied blocks, and also its own controls naturally.

NOTE: *The available mathematical functions and expressions for ProcessFlowDB are listed in the Online Manual of PhoeniX Database.*

4. The Process Validation In The Database

This section is dedicated to bring up the issue about process validation in FlowDB.

PhoeniX Cleanroom Database
Module : Process Flow Database

	Menu / Templates		
	Validation		
Hierarchy	Material	Relation	Check (*)
Equipments	Define the forbidden and the available materials for the equipment.		
Process Steps	The forbidden and the available materials inherited from the equipment.	Define the required preceding steps and the forbidden proceeding steps.	
Process Blocks		Define the required preceding blocks and the forbidden proceeding blocks.	Check the relation among the process steps used in a process block.
Process Flows			- Check the relation among the process steps used in a process block. - Check the relation among the process blocks used in a process flow.

Note : (*) These tasks are automatically done by the software.

Figure 4.1 The menu/templates for process validation in the Process Flow Database.

4.1 The Material Menu
-- the process validation at the equipment level --

The process validation in the database can be started at the equipment level by defining the available and the forbidden materials for the equipment.

Figure 4.1.1 The available and the forbidden materials for the RIE - Elektrotech Twin System PF340.

4.2 The Relations Menu
-- the process validation at the step, block, and flow levels --

At the processes level, the validation is defined inside the "Relations" menu. Below, as an example, the relation among the process steps are established: which steps are allowed and which ones are not allowed after and before a process step respectively.

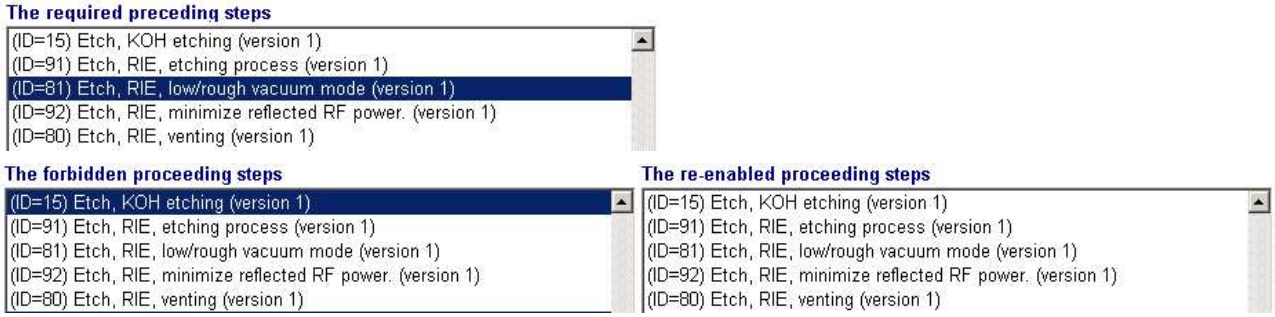

The required preceding steps
(ID=15) Etch, KOH etching (version 1)
(ID=91) Etch, RIE, etching process (version 1)
(ID=81) Etch, RIE, low/rough vacuum mode (version 1)
(ID=92) Etch, RIE, minimize reflected RF power. (version 1)
(ID=80) Etch, RIE, venting (version 1)
The forbidden proceeding steps
(ID=15) Etch, KOH etching (version 1)
(ID=91) Etch, RIE, etching process (version 1)
(ID=81) Etch, RIE, low/rough vacuum mode (version 1)
(ID=92) Etch, RIE, minimize reflected RF power. (version 1)
(ID=80) Etch, RIE, venting (version 1)
The re-enabled proceeding steps
(ID=15) Etch, KOH etching (version 1)
(ID=91) Etch, RIE, etching process (version 1)
(ID=81) Etch, RIE, low/rough vacuum mode (version 1)
(ID=92) Etch, RIE, minimize reflected RF power. (version 1)
(ID=80) Etch, RIE, venting (version 1)

Figure 4.2.1 The required preceding step and the forbidden proceeding steps for the process step "Etch,RIE,SF6,check/ set/read parameters" (ID 90).

Note: *the re-enabled proceeding steps are used when the forbidden proceeding steps can be applied after a certain preliminary steps. For example: KOH etching should never proceed RIE, except when the cleaning steps are performed beforehand. So* ***at*** *the cleaning step, which should be set after the RIE step, select the KOH etching in the box "The re-enabled proceeding steps".*

Specifically defined preceding and proceeding steps can avoid the confusion in the alignment of the process steps to perform a cleanroom process.

4.3 The Check Menu

This menu checks the materials used and the alignment of the process steps used in the process block.

This action will be automatically done by the database only if the process validations at the equipment level and the process step level were defined (refer to sections 4.1 and 4.2).

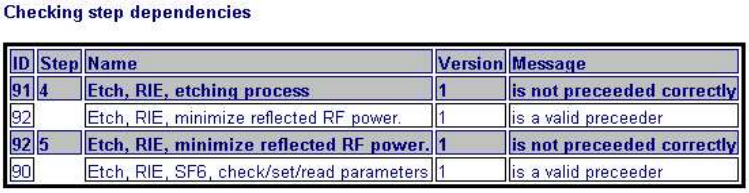

Checking step dependencies
ID Step Name Version Message
91 4 Etch, RIE, etching process 1 is not preceeded correctly
92 Etch, RIE, minimize reflected RF power. 1 is a valid preceeder
92 5 Etch, RIE, minimize reflected RF power. 1 is not preceeded correctly
90 Etch, RIE, SF6, check/set/read parameters 1 is a valid preceeder

Figure 4.3.1 Warning message when the process steps are alligned incorrectly, e.g. when the step "etching process" is set before the step "minimize reflected RF power".

The messages at figure 4.3.1 suggest that the step "minimize reflected RF power" should precede the step "etching process" , and the step "check/set/read parameters" should precede the step "minimize reflected RF power".

When the steps are alligned correctly, there will be no message.

5. The History
-- the quality improvement of the database --

This section is dedicated to bring up the issue about the quality improvement in FlowDB.

PhoeniX Cleanroom Database
Module : Process Flow Database

	Menu / Templates			
	Quality Improvement			
Hierarchy	Commit	New	Versions[1]	Usage[1]
Equipments	Committed equipment cannot be modified/ erased	Create the new version of the equipment.	- The available versions of an equipment. - The evolvement / development history of each version of an equipment.	The usage of a version of an equipment in the process steps & blocks & flows & batches.
Process Steps	Committed process steps cannot be modified/ erased	Create the new version of the process step.	- The available versions of a process step. - The evolvement / development history of each version of a process step. - The version of the equipment used in a process step.	The usage of a version of a process step in the process blocks & flows & batches.
Process Blocks	Committed process blocks cannot be modified/ erased	Create the new version of the process block.	- The available versions of a process block. - The evolvement / development history of each version of a process block. - The version of the equipment & process steps used in a process block.	The usage of a version of a process block in the process flows & batches.
Process Flows	Committed process flows cannot be modified/ erased	Create the new version of the process flow.	- The available versions of a process flow. - The evolvement / development history of each version of a process flow. - The version of the equipment & process steps & process blocks used in a process flow.	The usage of a version of a process flow in the batches.

Masks [2]	Commit	Version
	Committed masks cannot be modified/ erased	The version of the masks.

Notes : [1] These tasks are automatically done by the software.
[2] The mask's templates defines the masks that are used in the process steps.

Figure 5.1 The menu/templates for process quality improvement in the Process Flow Database.

5.1 The Commit, The Versions, And The Usage Menu

The well-built equipment and processes are committed/saved hence they become a static part of the database; the committed versions cannot be edited or deleted anymore.

As the technology and the equipment evolve, the committed versions may however need some improvement in the future. The improvement is done by creating a new version of them, so that their contents, e.g. the variables and the expressions, can be adjusted.

The new version is assigned to evolve from the committed one, but it can also be created from the not-yet-committed version. This implies several committed and several not-yet-committed versions exist, and they are related to each other.

The database provides the service that tracks and keeps the history of the available versions, the evolution of each version, and the relation between each version of the processes and the equipment.

The Versions Menu

The "Versions" menu reveals the available versions, their evolvement, and the versions of the applied processes and equipment.

Clicking the "Versions" menu in the Process Block "LPCVD SixNy (stress free) deposition" with ID 1 reveals the figure 5.1.1 below:

Versions from this process block

+ - ID	+ - Name	+ - Version	+ - Commited	+ - BasedOn	+ - MostRecent	+ - SELF
1	LPCVD SixNy (stress free) deposition	1	1	1	1	1
28	LPCVD SixNy (stress free) deposition	2	0	1	1	0

Versions of processsteps used in this processblock

+ - ID	+ - Step	+ - Name	+ - Version	+ - Commited	+ - BasedOn	+ - MostRecent	+ - SELF
4	1	Weight measurement	1	1	4	4	1
20	1	Weight measurement	2	0	4	4	0
3	2	Standard Cleaning	1	1	3	3	1
18	2	Standard Cleaning	2	0	3	3	0
2	3	Deposit LPCVD SiN	1	1	2	2	1
22	3	Deposit LPCVD SiN	2	0	2	2	0
23	3	Deposit LPCVD SiN	3	0	22	2	0
4	4	Weight measurement	1	1	4	4	1
20	4	Weight measurement	2	0	4	4	0

Versions of equipment used in processsteps in this processblock

+ - ID	+ - Step	+ - Name	+ - Version	+ - Commited	+ - BasedOn	+ - MostRecent	+ - SELF
6	1	Balance	1	1	6	25	1
21	1	Balance	2	0	6	25	0
25	1	Balance	3	1	21	25	0
3	2	Standard Cleaning	1	1	3	3	1
1	3	LPCVD oven 1	1	1	1	1	1
27	3	LPCVD oven 1	2	0	1	1	0
6	4	Balance	1	1	6	25	1
21	4	Balance	2	0	6	25	0
25	4	Balance	3	1	21	25	0

Versions of crossection models used in processsteps in this process block

+ - ID	+ - Step	+ - Name	+ - Version	+ - SELF
	1			
	2			
3	3	Isotropic etching / deposition	1	1

Figure 5.1.1 The versions of the Process Block "LPCVD SixNy (stress free) deposition" and the version of the used steps/equipments/cross-section. The contents of this menu is generated **automatically** by the database.

The contents of the box "Versions from this process block" :

- the available versions of the process block with their ID
- the committed version of the process block "LPCVD SixNy (stress free) deposition" is the one with ID 1.
- the second version of the process block "LPCVD SixNy (stress free) deposition" is evolved "BasedOn"

the version with ID 1.

– the "MostRecent" committed version is the version with ID 1.

NOTE: *The most recent version is* ***not*** *always the same with the latest one. The database refers the most recent version to the latest* ***committed*** *version, which is* ***not*** *necessarily the latest version of the processes. Attention should be paid on the revision timeline, which is fully described in the online Manual of PhoeniX ProcessFlowDB.*

The Usage Menu

The "Usage" menu reveals the application of a version in the ProcessFlowDB hierarchy.

Clicking the "Usage" menu in the Equipment "Balance" with ID 6 reveals the figure 5.1.2 below:

Equipment 6 (Balance, version 1) is used in the next listed process steps

+ - StepID	+ - Name	+ - Version	+ - Commited
4	Weight measurement	1	1

and thus in process blocks

+ - BlockID	+ - Name	+ - Step	+ - Version	+ - Commited
1	LPCVD SixNy (stress free) deposition	1	1	1
1	LPCVD SixNy (stress free) deposition	4	1	1
28	LPCVD SixNy (stress free) deposition	2	2	0

and thus in process flows

+ - FlowID	+ - BLock	+ - Step	+ - Name	+ - Version	+ - Commited
1	2	1	V-groove	1	1
1	2	4	V-groove	1	1
4	2	1	V-groove	2	0
4	2	4	V-groove	2	0

and thus in batches

+ - ProcessFlowID	+ - BatchID	+ - Block	+ - Step	+ - Version	+ - Commited
1	2	1	V-groove	1	1
1	2	4	V-groove	1	1
4	2	1	V-groove	2	0
4	2	4	V-groove	2	0

Figure 5.1.2 The application of the first version of the Equipment "Balance" with ID 6 in the Process FlowDB hierarchy. The contents of this menu is generated **automatically** by the database.

NOTE : *The "Usage" and the "Version" menu are available in* ***each level*** *of the process flow hierarchy (refer to* ***figure 5.1*** *).*

6. Conclusion

The Process Flow Module in the PhoeniX Clean Room Database is a tool to manage the documentation for the micro's and nano's cleanroom processes. It offers the flexibility but also the communication standardization to the various processes and technologies involved.

A properly managed database guarantees the accessibility of the available processes in the hierarchy. Also, most of the validation process will be able to be done automatically so that the confusion in the process alignment and the equipment contamination can be prevented. Finally, the regular update and maintenance of the database will secure the continuous improvement of its quality.